Nuclear Instruments and Methods in Physics Research A 718 (2013) 437–439

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

RPC hit contribution to CMS muon reconstruction at LHC

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ARTICLE INFO

Available online 29 August 2012

Keywords:
Gas detectors
RPC
Muon
CMS
LHC

ABSTRACT

The Resistive Plate Chambers (RPCs) are used as dedicated trigger detector in the both barrel and endcap regions of the CMS experiment together with Drift Tubes and Cathode Strip Chambers. The redundancy of the muon system of CMS is used also to improve the muon identification and reconstruction efficiency. We will describe the performance of the contribution of RPC hits in the muon identification and how they complement the main muon tracking devices.

1. Introduction

The Compact Muon Solenoid (CMS) is one of the two general purpose detectors built on the Large Hadron Collider (LHC) and muon is one of the objects playing important roles to investigate particle physics at the TeV energy scale including search for the Higgs boson, supersymmetric particles, etc. The Resistive Plate Chamber (RPC) is part of the muon detection system and is used for triggering purpose because of their good time resolution and high granularity.

A schematic view of the CMS detector is shown in Fig. 1. The muon system is divided into five wheels in the barrel and three disks in each endcap. Each barrel wheel is divided into 12 sectors, covering the full azimuthal dimension. Each sector consists of four layers of Drift Tubes (DTs) and six layers of RPCs. Drift Tube chambers and Cathode Strip Chambers (CSC) are used in the pseudo-rapidity regions of $|\eta|<1.2$ and $0.9<|\eta|<2.4$, respectively, and are complemented by the system of RPC covering the range of $|\eta|<1.6$.

In the standard CMS reconstruction for pp collisions, tracks are first reconstructed independently in the silicon tracker (tracker track) at the heart of the detector and in the muon system (standalone-muon track) installed outside the solenoid. Based on these objects, two muon reconstruction approaches are used. The first approach is global muon reconstruction (outside-in). In this approach, for each standalone-muon track, a matching tracker track is found by comparing parameters of the two tracks propagated onto a common surface, and a global-muon track is fitted combining hits from the tracker track and standalone muon track. The second approach is tracker muon reconstruction (inside-out). In this approach, all tracker tracks with the transverse momentum $p_T>0.5$ GeV/c and $p>2.5$ GeV/c are considered as possible muon candidates and are extrapolated to the muon system taking into account the magnetic field, the average expected energy losses, and multiple scattering in the detector materials. If at least one muon segment (a short track stub made of DT or CSC hits) matches the extrapolated track, then the corresponding tracker track qualifies as a Tracker Muon.

More detailed description of the CMS muon reconstruction can be found in Ref. [1]. This study is focused on the contribution of RPC hits to global muon reconstruction in the 2011 LHC proton–proton run at a center-of-mass energy of $\sqrt{s}=7$ TeV.

2. RPC hit contribution to muon reconstruction

The RPC detectors are employed in CMS as a dedicated trigger system both in the barrel and in the endcap regions. They complement the muon tracking system: Drift Tubes in the barrel and Cathode Strip Chambers in the endcaps. The condition of muon identification in global muon reconstruction is that there should be two matched muon segments or one matched muon segment in the case at least one RPC hit exists. So if any muon has only one matched muon segment, that muon will not be reconstructed if RPC hits are not complemented. Even in the case there are two matched muon segments, we found that some muons are not reconstructed if RPC hits are excluded in the fit.

Contribution of RPC hits to CMS muon reconstruction is studied by measuring global muon reconstruction efficiency including RPC hits and not including RPC hits, respectively. A tag-and-probe method [2], which is a well-established data-driven approach, is used to measure the efficiencies for both MC

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http://dx.doi.org/10.1016/j.nima.2012.08.056

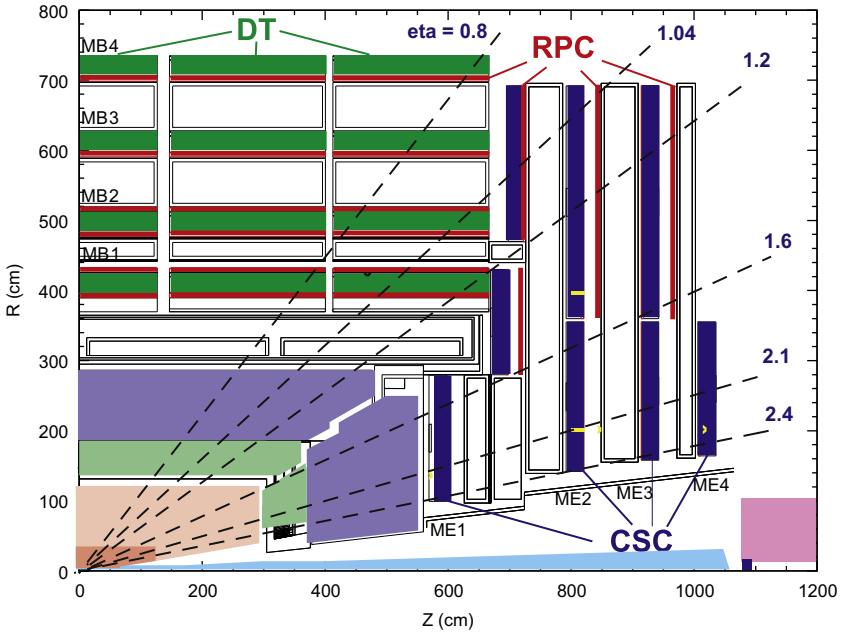

Fig. 1. Layout of one quadrant of the CMS detector. The four DT stations in the barrel, the four CSC stations in the endcap, and the RPC stations in both the barrel and the endcap.

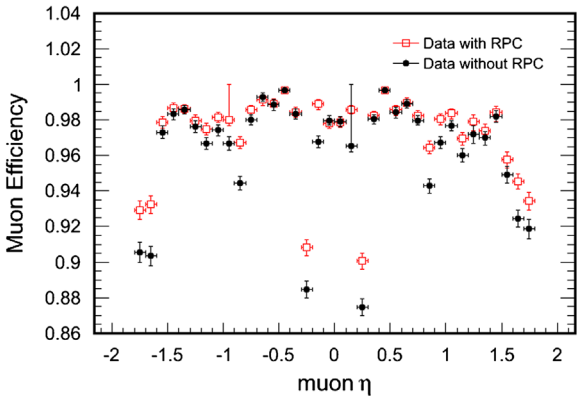

Fig. 2. Muon reconstruction efficiencies as a function of η for the Medium-Tight Muon selection. The boxes represent the efficiencies including RPC hits and the dots not including RPC hits. The plot is for data collected in 2011.

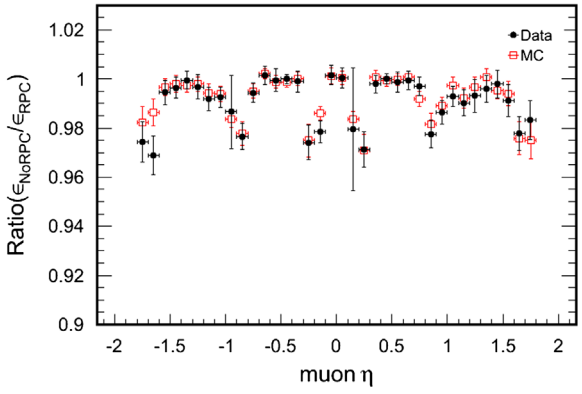

Fig. 3. The efficiency ratio for the Medium-Tight Muon selection: the efficiencies without RPC are divided by the ones with RPC. The boxes represent MC and the dots data.

and data. Z production is used to define tag-and-probe pair and the efficiency is obtained by fitting method.

A given physics analysis can achieve the desired balance between identification efficiency and purity by applying a selection based on various muon identification variables. In this study we investigate the RPC hit contribution to two global muon selections.

2.1. Contribution to Medium-Tight Muon selection

For this selection, the following conditions are required: normalized χ^2 of the global-muon track fit is less than 10; the number of tracker layers with hits used in the fit is greater than 8 (including at least one pixel hit) and have a transverse impact parameter $|d_{xy}| < 2$ mm with respect to the primary vertex.

Fig. 2 shows the muon reconstruction efficiency as a function of η for the Medium-Tight Muon selection with the muon $p_T > 20$ GeV/c. The boxes represent the efficiencies including RPC hits and the dots not including RPC hits. Fig. 3 shows the ratio of the two efficiencies, that is, the efficiencies without RPC are divided by the ones with RPC. We can see the efficiencies without RPC drop at certain η region by 3–4% compared to the ones with RPC. The regions where the efficiencies drop are the crack regions between adjacent wheels.

2.2. Contribution to Tight Muon selection

For this selection, the following two conditions are required in addition to Medium-Tight Muon selection: at least one muon chamber hit included in the global-muon track fit; matched to muon segments in at least two muon stations. The Tight Muon selection is used in many physics analyses in CMS, in particular in the measurements of inclusive W and Z cross-sections.

The same efficiency study as Medium-Tight Muon is done with Tight Muon selection and we have observed efficiencies without RPC drop in the similar η region to Medium-Tight Muon. In the case of Tight Muon, however, RPC contribution is more evident.

There is about 10% efficiency drop in the crack regions, whereas 3–4% drop in the case of Medium-Tight Muon. We have identified that the most muons causing the efficiency drop without RPC in the Tight Muon selection do not pass the requirement of at least one muon chamber hit included in the global muon track fit if RPC hits are excluded.

3. Conclusion

RPC contribution to CMS muon identification and reconstruction efficiency was studied using a tag-and-probe method in the Z production. It is observed that RPC hits could recover some muons specially at the crack regions between barrel wheels. The RPC contribution has no dependence on muon p_T or ϕ as far as p_T is greater than 20 GeV/c. The same RPC contribution study is being performed by tag-and-probe using J/Ψ production in order to investigate the RPC contribution to lower p_T muons.

Acknowledgments

We thank the colleagues in CMS RPC community and Muon Physics Object Group for their warm support and good advices.

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